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Measuring orthometric water heights from lightweight Unmanned Aerial Vehicles (UAVs)

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A better quantitative understanding of hydrologic processes requires better observations of hydrological variables, such as surface water area, water surface level, its slope and its temporal change. However, ground-based measurements of water heights are restricted to the in-situ measuring stations. Hence, the objective of remote sensing hydrology is to retrieve these hydraulic variables from spaceborne and airborne platforms. The forthcoming Surface Water and Ocean Topography (SWOT) satellite mission will be able to acquire water heights with an expected accuracy of 10 centimeters for rivers that are at least 100 m wide. Nevertheless, spaceborne missions will always face the limitations of: i) a low spatial resolution which makes it difficult to separate water from interfering surrounding areas and a tracking of the terrestrial water bodies not able to detect water heights in small rivers or lakes; ii) a limited temporal resolution which limits the ability to determine rapid temporal changes, especially during extremes. Unmanned Aerial Vehicles (UAVs) are one technology able to fill the gap between spaceborne and ground-based observations, ensuring 1) high spatial resolution; 2) tracking of the water bodies better than any satellite technology; 3) timing of the sampling which only depends on the operator 4) flexibility of the payload. Hence, this study focused on categorizing and testing sensors capable of measuring the range between the UAV and the water surface. The orthometric height of the water surface is then retrieved by subtracting the height above water measured by the sensors from the altitude above sea level retrieved by the onboard GPS. The following sensors were tested: a) a radar, b) a sonar c) a laser digital-camera based prototype developed at Technical University of Denmark. The tested sensors comply with the weight constraint of small UAVs (around 1.5 kg). The sensors were evaluated in terms of accuracy, maximum ranging distance and beam divergence. The sonar demonstrated a maximum ranging distance of 10 m, the laser prototype of 15 m, whilst the radar is potentially able to measure the range to water surface from a height up to 50 m. After numerous test flights above a lake with an approximately horizontal water surface, estimation of orthometric water height error, including overall accuracy of the system GPS-sensors, was possible. The RTK GPS system proved able to deliver a relative vertical accuracy better than 5-7 cm. The radar confirmed to have the best reliability with an accuracy which is generally few cm (0.7-1.3% of the ranging distance). Whereas the accuracy of the sonar and laser varies from few cm (0.7-1.6% of the ranging distance) to some tens of cm because sonar measurements are generally influenced by noise and turbulence generated by the propellers of the UAV and the laser prototype is affected by drone vibrations and water waviness. However, the laser prototype demonstrated the lowest beam divergence, which is required to measure unconventional remote sensing targets, such as sinkholes and Mexican cenotes, and to clearly distinguish between rivers and interfering surroundings, such as riparian vegetation.